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**Dr. Achim Wixforth**

**D-80626 München**

Device and Process for Matter Transport of Small Quantities of Matter

**Patent claims**

1. A process for specific and direct manipulation of small quantities of matter on solid-body surfaces,

   - in which, with the aid of one or more acoustic surface waves, an impulse is generated along the solid-body surface, whereby the surface wave is generated with a surface-wave generator (1, 27, 61, 95, 97, 99), and

   - the impulse (16,3 6, 105) is made to interact with at least one quantity of matter in order to cause movement on the surface in a desired direction (17, 39).

2. A process according to claim 1, in which, by functionalizing parts (15, 49, 83, 85, 87) of the solid-body surface, at least one defined trajectory is set for the quantity of matter and the at least one quantity of matter

will be moved by the impulse transfer along this at least one trajectory.

3. A process according to claim 2, in which the functionalization of the solid-body surface is achieved by grooves, barriers, lithographic definition of channels, or modulation of wetting properties.

4. A process according to claim 3, in which the functionalization is achieved by modulation of the wetting properties of the solid-body surface and the modulation of the wetting properties is achieved by lithographic definition of at least one hydrophobic region and at least one region that is hydrophilic in comparison to it or at least one lipophobic region and at least one region that is lipophilic in comparison to it.

5. A process according to claim 3, in which the functionalization of the solid-body surface is achieved by modulation of the wetting properties of the at least one part of the solid-body surface and the modulation of the wetting properties is achieved through silanization of this part of the solid-body surface.

6. A process according to one of claims 1 through 5, in which the acoustic surface waves are generated by electric stimulation.

7. A process according to one of claims 1 through 6, in which interdigital converters (1, 27, 31, 61, 95, 97, 99) are used to generate the acoustic surface waves.

8. A process according to one of claims 6 or 7, in which the acoustic surface waves are generated by means of the piezoelectric effect in a piezoelectric substrate or a piezoelectric region of a substrate.

9. A process according to claim 8, in which a piezoelectric layer is used on the substrate surface to generate the surface waves that is selected in such a way that it has different wetting properties than the rest of the substrate surface.

10. A process according to one of claims 1 through 9, in which the impulse transfer between the at least one acoustic surface wave and the at least one quantity of matter is transmitted by the electric fields accompanying the wave in the piezoelectric substrate or at least in the piezoelectric region of the solid-body surface.

11. A process according to one of claims 1 through 10, in which the impulse transfer between the at least one acoustic wave and the at least one quantity of matter is transmitted by the mechanical deformation of the solid-body surface that accompanies the surface wave.

12. A process according to one of claims 1 through 11, in which shear waves, Lamb waves, Rayleigh waves, Love waves, or combinations thereof are used as surface waves.

13. A process according to one of claims 1 through 12, in which surface waves of different frequencies ($f_1$, ..., $f_n$) are sent to different regions of the surface (5, 21, 37; $x_1$, ..., $x_n$).

14. A process according to claim 13, in which, to generate surface waves in different regions (5, 21) of the surface, at least two generators (1, 27, 31, 61, 95, 97, 99) with different operating frequencies are used for surface waves.

15. A process according to claim 7 and claim 14, in which the at least two generators include interdigital converters with constant but different distances between the fingers of each.

16. A process according to claim 7 and claim 13, in which, to generate surface waves of different frequencies, at least one interdigital converter (61, 95, 97, 99) with non-constant distances between the fingers is used.

17. A process according to one of claims 1 though 16, in which superimposition of at least two acoustic surface waves is used to establish the size and direction of the velocity vector of the at least one quantity of matter.

18. A process according to one of claims 1 through 17, in which the at least one quantity of matter is divided by at least one acoustic surface wave into at least two smaller subquantities.

19. A process according to one of claims 1 through 18, in which the at least one quantity of matter is analyzed within at least one region of the solid-body surface in regard to at least one physical, chemical, or biological characteristic.

20. A process according to claim 19, in which a part of the at least one quantity of matter is separated from the rest of the quantity of matter, either before or after the analysis.

21. A process according to one of* claims 19 or 20, in which the at least one quantity of matter is analyzed with at least one acoustic surface wave in regard to its size, its mass, its optical, magnetic, electric, and/or dielectric properties.
[* German "einem" should be "einem der"]

22. A process according to one of claims 1 through 21, in which at least one part of the at least one quantity of matter is modified in at least one region on the solid-body surface by chemical, physical, or biological processes.

23. A process according to claim 22, in which the at least one part of the at least one quantity of matter is modified by functionalizing at least one region of the solid-body surface with respect to its physical, chemical, or biological properties.

24. A process according to one of claims 19 through 23, in which the at least one quantity of matter to by analyzed or modified is immobilized reversibly and temporarily on at least one region of the solid-body surface by modulation or coating of this region of the solid-body surface through chemisorption or physisorption.

25. A process according to one of claims 1 through 24, in which the at least two quantities of material are brought into contact in at least one region (25 ) of the solid-body surface by specific and direct movement (17, 20) for purposes of being mixed and/or at least one physical, chemical, or biological reaction.

26. A process according to claim 25, in which at least two quantities of matter are moved toward each other with the aid of two surface waves running in opposite directions.

27. A process according to one of claims 1 through 26, in which surface waves are sent from various directions to the at least one quantity of matter, in order to achieve a mixing of the at least one quantity of matter.

28. A process according to one of claims 1 through 27, in which the at least one surface wave is generated by wireless irradiation of at least one electromagnetic wave into at least one generator (1, 27, 31, 61, 95, 97, 99) for surface waves.

29. A process according to one of claims 1 through 28, in which at least one additional surface wave is irradiated from a direction (37) onto the at least one quantity of matter that does not correspond to the original direction of movement (17) of the quantity of matter.

30. A process according to one of claims 1 through 29, in which at least one surface wave is sent approximately tangentially onto at least one quantity of matter, in order to place it in rotation.

31. A device for specific and direct manipulation of at least one quantity of matter on a solid-body surface, with:

- at least one device (1, 27, 31, 61, 95, 97, 99) for generating acoustic surface waves on the solid-body surface in at least one spreading direction (16, 21, 36, 91, 101),

- an interaction region, in which the quantity of matter can interact with the at least one surface wave, in order to cause a movement of the quantity of matter along the surface through an impulse transfer from the surface wave or surface waves.

32. A device according to claim 31, with at least one defined trajectory (15, 49, 83, 85, 87) for the movement of the quantity of matter.

33. A device according to claim 32, in which the at least one defined trajectory (15, 29, 83, 85, 87) includes a groove, a barrier, and/or a lithographically defined channel.

34. A device according to claim 32, in which the at least one defined trajectory is formed by a modulation of the wetting properties of the solid-body surface.

35. A device according to claim 34, in which the solid-body surface is partially silanized, in order to achieve a modulation of the wetting properties.

36. A device according to claim 34, in which the modulation of the wetting properties is formed by at least one hydrophobic region and at least one region that is hydrophilic in comparison to it or at least one lipophobic region and at least one region that is lipophilic in comparison to it.

37. A device according to claim 36, in which at least one hydrophobic region and at least one hydrophilic region or at least one lipophobic region and at least one lipophilic region are defined lithographically.

38. A device according to one of claims 36 or 37, in which the hydrophobic and/or hydrophilic or the lipophobic and/or lipophilic regions include a corresponding coating.

39. A device according to claim 34, in which the modulation of the wetting properties is achieved by lateral micro- or nanostructuring.

40. A device according to one of claims 32 through 39, in which the at least one defined trajectory (15) has a branch (14) to at least one additional defined trajectory.

41. A device according to one of claims 32 through 40, in which the at least one defined trajectory includes an essentially round region (49) and the at least one generator (1) for surface waves are arranged in such a way that a surface wave can be generated in a direction tangential to this round region.

42. A device according to one of claims 32 through 41, that includes a network of defined trajectories

and generators for surface waves, such that the at least one quantity of matter can be moved along the trajectories.

43. A device according to one of claims 32 through 42 with at least one generator (31) to generate a surface wave in a direction (36) that meets the quantity of matter moving along a trajectory from the side.

44. A device according to one of claims 32 through 43, with a defined trajectory to an external supply reservoir.

45. A device according to one of claims 32 through 44, with a defined trajectory to an external receiving reservoir.

46. A device according to one of claims 31 through 45, in which at least one part of the solid-body surface is designed as a supply reservoir (11, 23, 71, 73, 75) for delivery of at least one quantity of matter.

47. A device according to one of claims 31 through 46, in which at least one part of the solid-body surface is designed as a receiving reservoir (13, 25, 45, 47, 51, 53, 77, 79, 81).

48. A device according to one of claims 31 through 47, with a piezoelectric substrate or a substrate with a piezoelectric region.

49. A device according to claim 48, in which there is a protective layer on the piezoelectric substrate or above the piezoelectric region, with a thickness that is less that the penetration depth of the surface wave, to protect the material to be moved.

50. A device according to claim 49, in which the protective layer includes quartz.

51. A device according to claim 48, in which there is a piezoelectric layer on a substrate with predetermined surface characteristics to stimulate of surface waves.

52. A device according to claim 51, in which the surface-wetting properties of the piezoelectric layer are different from the wetting properties of the surrounding substrate.

53. A device according to one of claims 31 through 52, in which several surface-wave generators (61, 95) are arranged in such a way that the impulses generated by the surface wave are added give a total impulse (105) in the direction of a desired direction of movement.

54. A device according to one of claims 31 through 53, with at least two surface-wave generators, the spatial radiations from which run 180 degrees opposite to each other, at least in part.

55. A device according to one of claims 31 through 54, in which a region of the solid-body surface is functionalized by modulation or coating of the solid-body surface through chemisorption or physisorption for reversible and temporary immobilization of the at least one quantity of matter.

56. A device according to one of claims 31 through 55, in which at least one interdigital converter (1, 27, 31, 61, 95, 97, 99) is provided as a device for generating surface waves.

57. A device according to one of claims 31 through 56, in which the at least one generator (61, 95, 97, 99) for surface waves is designed in such a way that the spreading region ($x_1$, ..., $x_n$) of the surface waves is changed with the frequency ($f_1$, ..., $f_n$).

58. A device according to claim 57, in which several generators are provided in order to generate surface waves with different spreading regions in several generating directions (1, 27, 31, 61, 95, 97, 99) for surface waves of different operating frequencies.

59. A device according to claim 58, in which the several interdigital converters are provided with constant but different distances between their fingers.

60. A device according to claim 57, in which at least one interdigital converter (61, 95, 97, 99) is provided with non-constant distances between fingers, to generate surface waves with different spreading regions.

61. A device according to one of claims 31 through 60, with a region in which the solid-body surface is provided with an element for local heating.

62. A device according to one of claims 31 through 61, with at least one antenna device for wireless irradiation of an electromagnetic wave into the at least one generator (1, 27, 31,61, 95 , 97, 99) for surface waves.

63. Use of a process according to one of claims 1 through 30 or a device according to one of claims 31 through 62 for specific and direct manipulation of liquids, gases, solid bodies, or combinations, mixtures, and/or dispersions thereof.

64. Use of a process according to one of claims 1 through 30 or a device according to one of claims 31 through 62 for specific and direct manipulation of inorganic reagents or organic materials, such as cells, molecules, macromolecules, or genetic materials produced *in vitro* or *in vivo*.

65. Use of a process according to one of claims 1 through 30 or a device according to one of claims 31 through 62 to analyze, synthesize, separate, mix, or proportion a small quantity of matter.

66. Use of a process according to one of claims 1 through 30 to move a small quantity of matter from a supply reservoir (11, 23,71, 73, 75) to a receiving reservoir (13, 25, 45, 47, 51, 53, 77, 79, 81).

67. Use of a process according to claim 40 to centrifuge a small quantity of matter.